

# Are robots our futures coaches?

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**Abstract--** The robots are coming in our daily lives: companion robots, service robots, sociable robots, assistant robots, and so on. It is difficult to imagine their real roles in the future because humans' expectations seem unclear, probably because robots are new and little known. It is thus important to put human beings in relation with robots to understand what they want. This paper describes an experimentation which explored the added value of a robot in a memory game with 67 persons comparing three conditions: computer game, robot game, or computer and robot game. Results showed that robot increased their performance perception and seemed to give them assurance. Results showed that the robot could be a natural coach for people.

**Index Terms--** Human-Robot Interaction, memory game, acceptance, workload

## I. INTRODUCTION (SIZE 10)

“The robots are coming, the robots are coming” wrote Norman Caplan [1] in 1982. Twenty-three years later, Lars Erik HolmQuist [2] was writing “The robots are coming”. Was not there any difference over the years? Was not there a dramatic advance in robotics? In 1982, Norman Caplan indicated that robots were industrialized machine made to automate tasks and replace human beings in complex tasks. It was not technologically possible to create other types of robots: “the research involved with adding human-like sensing and intelligence to a machine is a real challenge in robotics field”. In 2005, the review was different. Lars Erik HolmQuist explained that robot definition had tremendously changed. In his mind, even tangible interfaces were robots in addition to dog robot, automatic vacuum cleaners and so on. Definitions and preoccupations had changed: communication between robots, robots collaboration, cuddles with robots, and so on. But, basically, robots were still expected. Today, robot definition is unclear. What we expect today is unclear. It becomes a necessity to understand what human beings need. It will design our futures robots and decide of their roles in our society. In this paper we investigate robot added value on a memory game. Are robots useful in this type of task? What about their behavior or their role in this type of task? We choose a memory one because the intrinsic nature of such a game does not lead to emotions like joy or anger. It requires concentration and generally people have neutral feelings when playing this game. Section II explores current researches about human-robot interaction. Section III introduces the tested game and explains material and methods used for the experimentation. Section IV, describes the evaluation

made with 67 participants. Section V shows results. And section VI concludes this paper.

## II. HUMAN-ROBOT INTERACTION

Bill Gates [3] recently gave his opinion about robots. He wrote that robotic advance seems similar to computers one third years ago. Thus, he predicted that robots will soon be in every home especially because hardware cost decreases year after year. But what are actually robots? Takanori Shibata [4] explained in 2004 that there are two categories of robots: industrial robots and service robots. There are service robots for professional use and service robots for personal and private use, developed to interact with human beings. In his point of view, service robots are evaluated with objective measures (speed, accuracy) and with subjective measures (joy, comfort). That is why we think this kind of robots is most challenging. Indeed, difficulties induced by industrial robot are only related to technological capabilities. But personal service robots have not only technological obstacles but also psychological ones. In parallel, Cynthia Breazeal [5] introduced the term: sociable robots. In her mind, “sociable robots are socially participative “creatures” with their own internal goals and motivations”. On their side, Dautenhahn and Billard [6] proposed that “Social robots are embodied agents that are part of heterogeneous group: a society of robots or humans. They are able to recognize each other and engage in social interactions, they possess histories (perceive and interpret the world in terms of their own experience), and they explicitly communicate with and learn from each other”. Another definition from Lin et al [7] indicated that a robot is “an engineered machine that senses, thinks and acts”. Actually, robots are easily thought to be life-like creature living among us [8]. This vision may come from science fiction and raises some ethical problems [7]: how can we ensure that robot will not be hacked? How can we ensure that they will not have bugs? If they live among us, which right will they have?

To avoid a part of these hypothetical problems, it is important to study not only robots but also humans: what should/should not do a robot? What do people want/do not want? Enz et al [9] asked people about their expectation. Results indicated that future robots should be utilitarian and affective. This result can be debatable because they are based on people imagination. But there is a bias induced by science fiction movies. People may have preconceptions. Indeed, Fussell et al [10] demonstrated that there are a disjuncture between anthropomorphism in people's spontaneous reactions to robots in social context and anthropomorphism in their

more carefully considered conceptions of robots. Authors indicated that “we might expect people’s abstract conceptualizations of robots to become more and more anthropomorphic as robots penetrate daily life and daily conversation.” This idea is shared by Kaplan [11] who hypothesizes that “the robot value profile is similar to notebooks one. Its value keeps increasing over time, as the user fills it with precious content”. Thus, is it relevant to ask people to imagine futures robots? People do not really know what they want. They would like the robot to be an assistant, an appliance or a servant not really a friend or a mate, but they would like robots communicate like humans without having human appearance [12].

To create futures robots, it is thus important to put humans in relation with robots and to observe their reactions. In this way, we already learnt, for example, that robot provides a presence which has a positive impact on human enjoyment and facilitates robot acceptance [13], that an emotional robot increases enjoyment and that people do not have the same reaction according to their age [14]. For example, 8 years old children are more expressive and happier to interact with robots than 12 years old children.

It is interesting to wonder whether the robot is always useful. That is why we explored the added value of a robot in a memory game. Which role could have a robot in this context among roles (a coach, a teacher, a colleague...) suggested by Duhaut and Pesty [15]?

### III. MATERIAL AND METHODS

#### A. Game principle



NaoSimon is an adapted Simon game played with the Nao robot. Simon is an electronic game of memory skill. The device has four colored buttons (red, green, yellow and blue), each producing a particular tone when it is pressed. In our experiment, red was associated to C3 (Do 2), green to E3 (Mi 2), yellow to G3 (Sol 2) and blue to B3 (Si 2). The device lights up one or more buttons in a random order. Then, the player must reproduce that order by pressing the correct buttons. This constitutes a round of the game. When the player wins a round, he/she knows that a color is added and thus the number of buttons to be pressed increases. Our version of Simon game was implemented on a tactile tablet PC. Nao, a robot built by French company Aldebaran Robotics, is associated to the game in order to be a player partner.

#### B. Architecture

NaoSimon has been developed with the ArCo architecture [16], which allows a set of devices to communicate together (and to be compatible). Thus, input and output devices can easily be linked. Moreover, the ArCo architecture offers a visual programming interface which can be used to rapidly create interaction scenarios without having computing knowledge [17][18]. NaoSimon is composed of four modules: Nao,

SimonFrame, SimonGame and Interpreter as shown in Fig. 1. A server manages the communication between each module and a Connector module describes the communication links. In this case, there is bidirectional communication between SimonFrame and Interpreter, and between SimonGame and Interpreter. And there is a unidirectional communication between Interpreter and Nao.

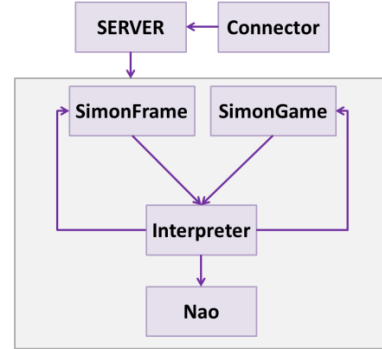


Fig. 1: NaoSimon ArCo modules

SimonFrame is the Graphical User Interface which contains the four colored buttons. When user presses a button, SimonFrame sends a message to Interpreter indicating which button has been pressed. SimonGame is the game engine. It generates sequences and manages player and robot turns. It receives orders from Interpreter, and indirectly from SimonFrame. It has the following capabilities: to initialize the game with a sequence size, to stop the game, to indicate the color which must be played by computer/robot, to start the player turn which indicates to SimonGame that player input has to be taken into account or to stop player turn. It can also indicate which color has been chosen by the player. If the player chose a wrong color, a “wrong answer” message is sent to the interpreter. If the player sequence is correct, a “good answer” message is sent to the interpreter.

Nao is the module which pilots the robot. When it receives a “red”, “green”, “yellow” or “blue” message, it presses the corresponding button. And, Interpreter is the module which interprets the game scenario. First, the robot greets the player and invites her/him to play a game. Player has to press the “black button” to begin. Nao starts to play, pressing buttons in the order given by SimonGame. When the sequence is finished, Nao requests the player to reproduce it. If the sequence is correct, player adds a new color whereas Nao adds three new colors each time. The game is stopped after three iterations. The final sequence contains eleven colors to memorize. Nao has several reactions (speech and gesture) according to the situation. The possible sentences told by the robot are shown in the Table I.

TABLE I  
SENTENCES SAID BY NAO

I	The player succeeds	The player fails
1	OK! My turn now.	Ha ha, my grandmother could be better than you!
	Well, so, I’m adding three notes.	
	Not bad, let’s keep playing.	
2	Hhmm, you seem strong at this game.	Ri... Di... Cu... Lous!
	Well, can you memorize that?	
	You are a competitor, let’s keep playing.	
3	Great, you are strong. I’m stopping now.	Oh, I thought I will

You won the game, congratulations.	beat you later.
Well done, you are se serious opponent.	

### C. Experimental conditions

#### Preliminary experiment

To reach our objective, we conducted a preliminary experiment during an engineering school open day. The experimentation took place in a room where groups of people came to receive information about the school. Thus, participants were not isolated and played a game in front of other people. The 22 volunteers were asked to play a game with Nao and to answer a few questions (detailed in the next part). There were 17 men and 5 women (mean age: 29.1 years old). This experiment informed that Nao was not judged useful (50.68%). Some participants indicated that it was useless because the entire game could be implemented on the tablet. Moreover, 55.1% of participants felt a temporal pressure although the game was not timed. It seemed that men judgment was more harsh than women one. Finally, 37.2% of participants felt discouraged, bored, angered or stressed.

This preliminary experiment and its results posed real challenges. (1) Which was responsible for these negative results (e.g. experimental conditions, robot)? (2) Is the robot judged more useful if there is no tablet? (3) Is there a real difference according to gender? Thus, we decided to compare three versions of NaoSimon to reach these objectives (i.e. tablet and robot together, robot alone, and tablet alone) and explored the player acceptability in these three experimental conditions and the player feeling of effort.

#### Three experimental conditions

We used three NaoSimon versions. The first experimental condition, shown in Fig. 2, put the player in relation with the tablet PC and Nao. Nao was placed near the tablet in order to be able to touch the screen and press the button. The robot was considered as a second player.

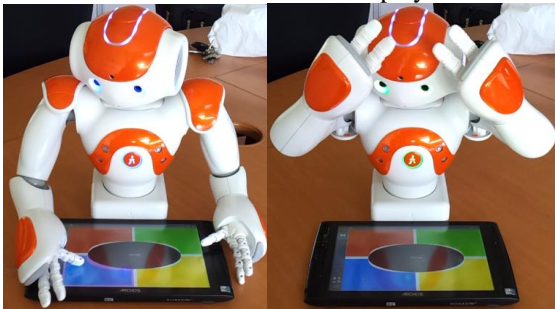


Fig. 2: First experimental condition of NaoSimon. Left: Nao's playing. Right: Nao's reaction when player lost.

The second experimental condition, shown in Fig. 3, put the player in relation with Nao only. Nao held colored signs to indicate color. Signs position respected the screen color position. Without tablet to interact, players had to use Nao's vocal recognition to play. Thus, tones were replaced by color names pronounced by the robot. Players were given a last cue to memorize colors: Nao's eyes and chest changed color too. The game scenario was the same than previously explained.



Fig. 3: Second experimental condition of NaoSimon. Left: Nao's playing. Right: Nao's reaction when player lost.

The third experimental condition, shown in Fig. 4, put the player in relation with the tablet PC only. Nao's voice was recorded and played by the tablet PC. The game scenario was unchanged.



Fig. 4: Third experimental condition of NaoSimon. Example of a pressed button.

The following part describes the global experimentation. The three situations are not described independently. Notice that when Nao is mentioned, it corresponded to its voice in the third experimental version.

### D. Experimentation

#### Participants

We recruited 67 volunteer participants (20 men, 47 women; mean age: 34.7 years old; range: 8 to 62 years old). None was computer specialist. We focused our interest on the widest possible naive population, who may not have fixed opinion about robots. That's why our population was composed of city-dwellers, country-dwellers, students, secretaries, psychologists, manual workers, people who do not like to play games, grandparents, parents, children, and so on.

#### Experimental setting

Experiment took place in an isolated room without disturbing noises, either at the laboratory or at participant's home. Experimental setting is shown in Fig. 5. Each participant was alone with the experimenter. Nao and/or the tablet PC were installed on an empty table. Each participant seated in front of Nao. The experimenter was installed at the other side of the table and supervised a computer which controlled the game. As soon as possible, the experimenter was not sitting down face to face with the participant. Experimenter had to be as discreet as possible to not disturb the participant during the game (e.g. not allowed to speak during the game). A film camera was placed at the table corner in order to record participant's face, reactions and speech.

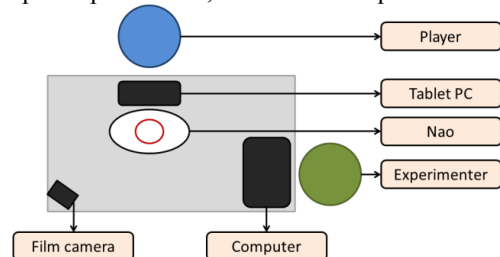


Fig. 5: Experimental setting

Before beginning the experiment, each participant received instructions from the experimenter. First, Simon game was explained (i.e. what is it? What are the rules?). Then, the adapted game NaoSimon and its rules were described as following. Nao started the game with playing a sequence of three colors. Then, the participant had to repeat the sequence and to add a new color in the sequence. Each round, Nao added three colors although the participant added only one. At last and before beginning the experiment, Participant had to give their oral and written consent, including her/his authorization to be video recorded. The experiment started when participant indicated she/he was ready. In the second condition (Nao only) participants began with a learning process realized in order to make them more familiar with the vocal recognition. They had to say “red”, “yellow”, “blue” or “green” ten times to see whether the robot was able to recognize them.

The game was composed of three levels of difficulty. At the first level, the participant had to memorize the initial sequence composed of three colors. At the first level, she/he had to memorize seven colors (initial sequence + 1 color added by participant + 3 colors added by Nao). At the last level, there were eleven colors to repeat (previous sequence + 1 color added by participant + 3 colors added by Nao). When the participant made a mistake, the game stopped immediately. Thus, experimental duration and difficulty level were not similar across participants.

#### IV. EVALUATION

##### A. Questionnaire

After the game, each participant had to fill a questionnaire which was composed of 13 questions (Table II). The first six questions asked about participant acceptability. We chose questions that were already used in other experimentations [19]. The following six questions were extracted from the NASA Task Load Index (TLX) questionnaire [20]. The NASA TLX is a scale which allows computing a subjective workload felt by a human performing a task. It evaluated six parameters: mental demand (MD; question 7), physical demand (PD; question 8), temporal demand (TD; question 9), performance (OP; question 10), effort (EF; question 11), and frustration level (FR; question 12). The workload can determine the levels of comfort, satisfaction, efficiency, and safety felt by a person. It was interesting to use this scale to compare the workload of the three conditions. It can indicate if the robot was constraining for people. Finally the last question asked about perception of robot utility. Participants had to answer using their own definition of utility. It allowed us to realize what was the most important for people. In the third condition (tablet PC only), questions 4, 5, and 6 were adapted replacing “Nao” by “tablet”.

TABLE II  
ASKED QUESTIONS

1. Did you enjoy playing with this game?
2. Would you like to have this game at home?
3. Were the game rules easy to understand?
4. Do you think Nao timely spoke or move? Was this intervention

relevant?
5. Would you like to be able to decide whenever Nao has to make movement or speak, to change game rules, to personalize the game?
6. If Nao was able to learn from your action, would you like it to automatically adapt your preference?
7. How much mental and perceptual activity was required?
8. How much physical activity was required?
9. How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred?
10. How successful do you think you were in accomplishing the goals of the task set by the experimenter?
11. How hard did you have to work to accomplish your level of performance?
12. How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?
13. Did you find that the robot was useful?

To answer the questions, participants had to choose an answer between low and high (Fig. 6), or good and poor for the question 10. It represented in face a percentage where low was 0 % and high was 100%. Participants had to put a cross on the line to indicate their answer. For example, if they really enjoyed the game, they put a cross next to High. The position on the line indicated the percentage value.

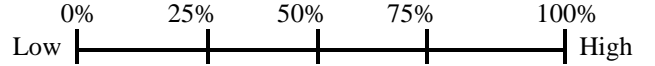


Fig. 6: Answer type example

Question 13 allowed us to gather participants in two groups: the ones who considered Nao as useful and the others who considered Nao as not useful. To do this, we used the median value of the score to divide our population in the first and the second experimental conditions (not in the third as only Nao's voice was used).

##### B. Workload during the game

To compute the workload, two independent researchers had rated the six parameters according to the procedure described in [20]. First they determined the most significant source of workload, for the game, in each pair. The consensus is shown in Fig. 7. To compute the workload of a participant, each questionnaire results were transformed into the corresponding percentage value (named below MD, PD, TD, OP, FR and EF). Notice that maximum TLX Workload score is 100. Thus, in our case, the score was computed as followed:

$$\text{TLX Workload} = \text{MD} \times 4 + \text{PD} \times 0 + \text{TD} \times 3 + \text{OP} \times 3 + \text{FR} \times 1 + \text{EF} \times 4 / 15$$

MD	= 4
PD	= 0
TD	= 3
OP	= 3
FR	= 1
EF	= 4
SUM	= 15

Fig. 7: NASA-TLX rating scales

Moreover, we studied the real performance level using a scale which indicated the progress in the game. During a full game session, participant had to do 24 button clicks as shown in Table III. We considered each click with the same difficulty level (linear progress) even if it became more difficult with time. So, performance level was computed as followed:

Real performance = correct click number \* 100 / 24.

For example if a participant had a mistake at the last memorized color of the second iteration, we considered her/his real performance as 41.67%.

TABLE III  
PARTICIPANTS ACTIONS

Iteration 1	A - A - A - A
Iteration 2	A - A - A - A - A - A - A - A - A
Iteration 3	A - A - A - A - A - A - A - A - A - A - A - A - A - A

Then, we created a ratio between the felt performance (question 10) and the real performance. When ratio was higher than 1, the participant thought that he/she was more successful in accomplishing the goals of the task set than in reality. When ratio was lower than 1, the participant thought that he/she was less successful in accomplishing the goals of the task set than in reality. A ratio of 1 constituted a perfect concordance between the real performance and the felt performance.

### C. Statistical analysis

Data analyses used Minitab 15© software. The accepted P level was 0.05. Data collected were nominal (e.g. gender, useful/not useful) and continuous (e.g. question's scores, TLX Workload, age, ratio between the real performance and the felt performance). As our data were not normally distributed, we used nonparametric statistical tests to answer to our study's aims: Mann-Whitney U test and Pearson correlation test.

## V. RESULTS

All participants fulfilled the 13 questions proposed. Considering them, high mean scores (score >70%) were reported for question 3 (86.3%±10.5%), question 4 (84.7%±9.5%), question 6 (75.4%±13.4%), question 5 (72.5%±13.8%) and question 1 (71.9%±9.5%). Middle mean scores (30%<score<70%) were reported for question 13 (62.4%±15.2%), question 10 (57.9%±14.2%), question 2 (51.8%±14.3%) and question 7 (47.7%±12.7%). Low mean scores (score<30%) were reported for question 9 (22.6%±13.4%), question 12 (18.3%±12.2%), question 11 (16.1%±9.9%) and question 8 (9.8%±8.2%).

Concerning the workload, the mean TLX was 34.3±62%. At last, mean ratio between the real performance and the felt performance was 1.2±0.5.

### A. Effect of the experimental conditions

Figure 8 shows the questionnaire results according to the experimental conditions. No significant difference was reported (all Mann-Whitney tests  $p>0.05$ ). However, the mean score of question 2 tended to be higher in second experimental condition than the first experimental condition ( $U=452.5$   $p=0.08$ ) and the third experimental condition ( $U=569.5$   $p=0.0795$ ).

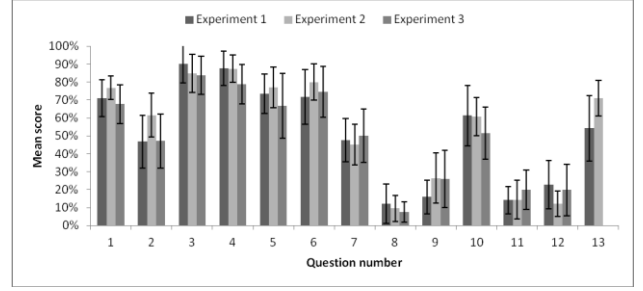


Fig. 8: Participant's answers to our 13 questions according to the experimental conditions (the question's statements were gathered in Table II). Level of significance:  $p<0.05$ , here all Mann Whitney U-tests were not significant.

Significant differences were observed in mean ratio between the real performance and the felt performance according to the experimental conditions (Figure 9). Mean ratio was higher in the second experimental condition than in the first and the third experimental conditions ( $U=375.5$   $p=0.037$  and  $U=576.5$   $p=0.007$  respectively). Mean ratio was higher in the first experimental condition than in the third experimental condition ( $U=495.5$   $p=0.034$ ).

No significant difference was reported in the mean TLX Workload according to the experimental conditions (all Mann-Whitney tests  $p>0.05$ ).

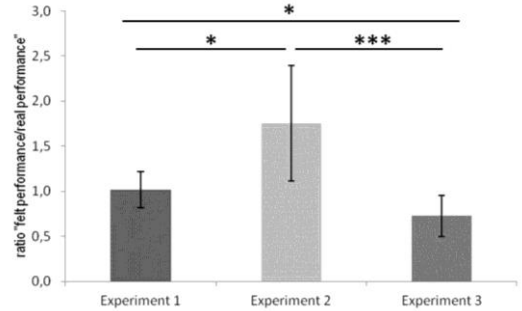


Fig. 9: Mean ratio between the real performance and the felt performance according to the experimental conditions. Significance level: \* for  $p<0.05$ , \*\* for  $p<0.01$  and \*\*\* for  $p<0.001$  (Mann-Whitney U-test)

We studied the link between this TLX Workload and questions 1 to 6 in each experimental condition. In the first experimental condition, higher the mean TLX Workload was, lower was mean score of question 1 ( $\rho=-0.423$   $p=0.044$ ). No correlation was reported in the second experimental condition (all  $p>0.05$ ). In the third experimental condition, higher the mean TLX Workload was, lower were mean scores of both question 3 ( $\rho=-0.549$   $p=0.008$ ) and question 4 ( $\rho=-0.456$   $p=0.033$ ).

We studied the link between this TLX Workload and mean ratio between the real performance and the felt performance in each experimental condition. No correlation was reported in the three experimental condition (all Pearson correlation test  $p>0.05$ ).

Two groups were created using median score of question 13: the ones who considered Nao as useful and the others who considered Nao as not useful. In the first situation, median score was 50% thus 14 participants considered Nao as useful and the others 9 participants considered Nao as not useful. In the second situation, median score was 75% thus 14 participants considered Nao as useful



and the others 8 participants considered Nao as not useful. In first experimental condition, the groups considered Nao as useful had higher scores on question 1 ( $75.3\% \pm 11.3\%$ ) and question 2 ( $59.3\% \pm 13.6\%$ ) than the groups considered Nao as not useful (question 1:  $64.4\% \pm 8.2\%$ ; question 2:  $27.2\% \pm 10.2\%$  respectively) (all Mann Whitney U-tests  $p < 0.05$ ). In second experimental condition, the groups considered Nao as useful had higher scores on question 1 ( $81.8\% \pm 5.2\%$ ) and question 2 ( $70.3\% \pm 9.9\%$ ) than the groups considered Nao as not useful (question 1:  $68.1\% \pm 6.6\%$ ; question 2:  $46.2\% \pm 12.8\%$  respectively) (all Mann Whitney U-tests  $p < 0.05$ ). At last, in second experimental condition, the groups considered Nao as useful had lower scores on question 12 ( $8.2\% \pm 5.8\%$ ) than the groups considered Nao as not useful ( $18.7\% \pm 8.4\%$ ) ( $U=132$   $p=0.047$ ).

#### B. Effect of the participant's age and gender

Here, we gathered the three experimental conditions. Some links existed between participant's age and question mean scores. Older the participant was, higher was mean score of question 8 ( $\rho=0.323$   $p=0.008$ ). Older the participant was, lower was mean score of question 5 ( $\rho=-0.312$   $p=0.010$ ). Concurrently, some differences existed on some question mean scores according to participant's gender. The mean score of question 5 was higher for men ( $83.7\% \pm 12.1\%$ ) than for women ( $67.7\% \pm 13.8\%$ ) ( $U=267$   $p=0.01$ ). The mean score of question 1 tended to be higher for men ( $78\% \pm 7.6\%$ ) than for women ( $69.2\% \pm 10\%$ ) ( $U=356$   $p=0.059$ ). No association was reported between mean TLX Workload and the participant's gender ( $U=102$   $p=0.875$ ) and age ( $\rho=-0.02$   $p=0.871$ ). No significant difference was reported in the mean ratio between the real performance and the felt performance according to the participant's gender ( $U=1364.5$   $p=0.624$ ) and age ( $\rho=0.13$   $p=0.317$ ).

### VI. CONCLUSION

This paper presented an experimentation which evaluated the added value of a robot in a memory game. We compared three conditions: robot with tablet (condition 1), robot only (condition 2), and tablet only (condition 3). We analyzed acceptance and workload in the three conditions. It appeared that there was no difference between them concerning the perceived workload. It may indicate that the robot was not perceived as stressful or annoying. It seemed that the robot was not perceived as an additional difficulty.

Concerning the first condition, people who felt workload did not like the game and did not want to have this game at home. It brings to the following question: was the workload due to the fact that they did not like the game, exonerating the robot. This result was not similar in the second and third condition. Was it a problem for people to interact with tablet and robot? Their association might be a problem.

In the first and second conditions, people who judged the robot useful wanted to have the game at home and liked it. Was the robot presence responsible for this result?

In the second condition, people who judged the robot useful felt less stress, annoyance, discouragement than others. Does it mean that robot have interesting properties against stress? Or did the robot stress other people?

Concerning the third condition, people who felt workload did not find game rules easy and did not find that tablet made relevant interventions. They felt a lack of indications. The level of feedback seemed important to them in this condition although it was not the case in other conditions. Did the robot give them impression to feedback although there was no behavioral difference in the three conditions? Was its presence comforting?

In all conditions, there was no difference between genders although there were differences between ages. The oldest participants did not want to personalize the game and felt a physical demand to do the task. It seems thus important to take age into account when a robot has to interact with people.

Generally, more participants wanted to have the game at home in the second condition. And generally, the felt performance was better than reality in this condition (robot alone). However, the robot has a neutral behavior and did not support participants. Does it mean that robots are natural coaches since people evaluated their performance better than reality? Does it mean that, in people mind, a robot has to be autonomous and self-sufficient since it received less good appreciation when it was associated with tablet?

This experimentation brought several new questions. We will analyze videos to try to answer them.

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